Industrial Demand and Applications for Solid Film Lubricants

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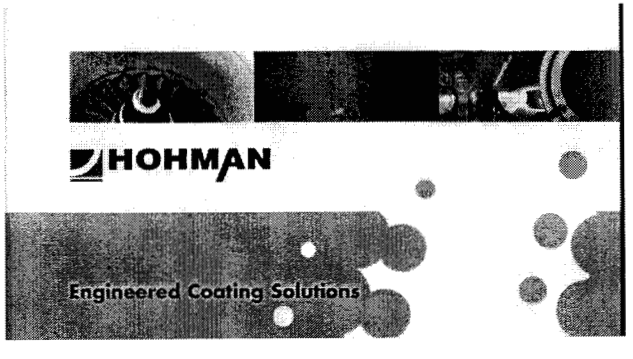


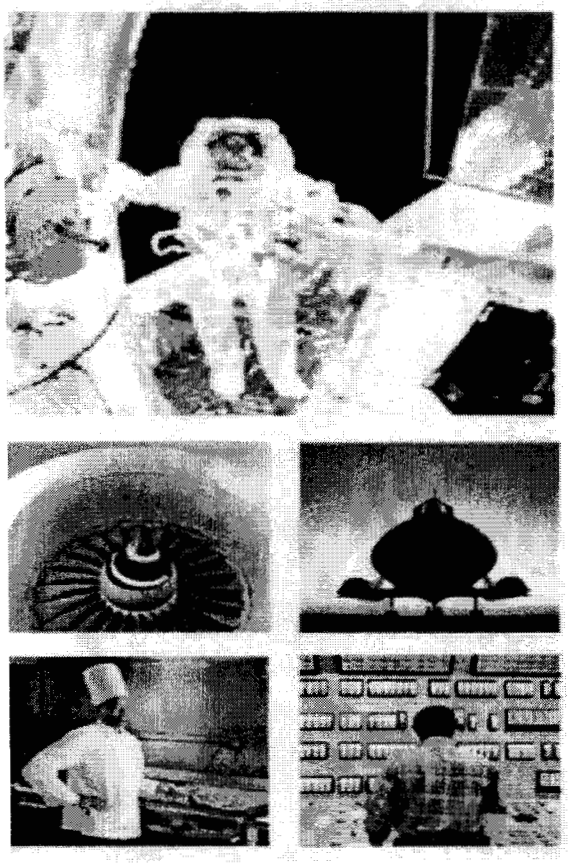
JPL

Outline of Presentation

- Solid film lubrication over last 30 Yrs.
- Application failures = lessons learned and motivation for technology advancement
- Advances in solid film lubes
- Advances in deposition technologies
- Advances in business practices
- Specific applications: Spray, Thermal, PVD, Conversion, Electro & Electroless Plating, combinational
- Conclusions

Growth in the field of Solid Film Lubricants (1 of 2)

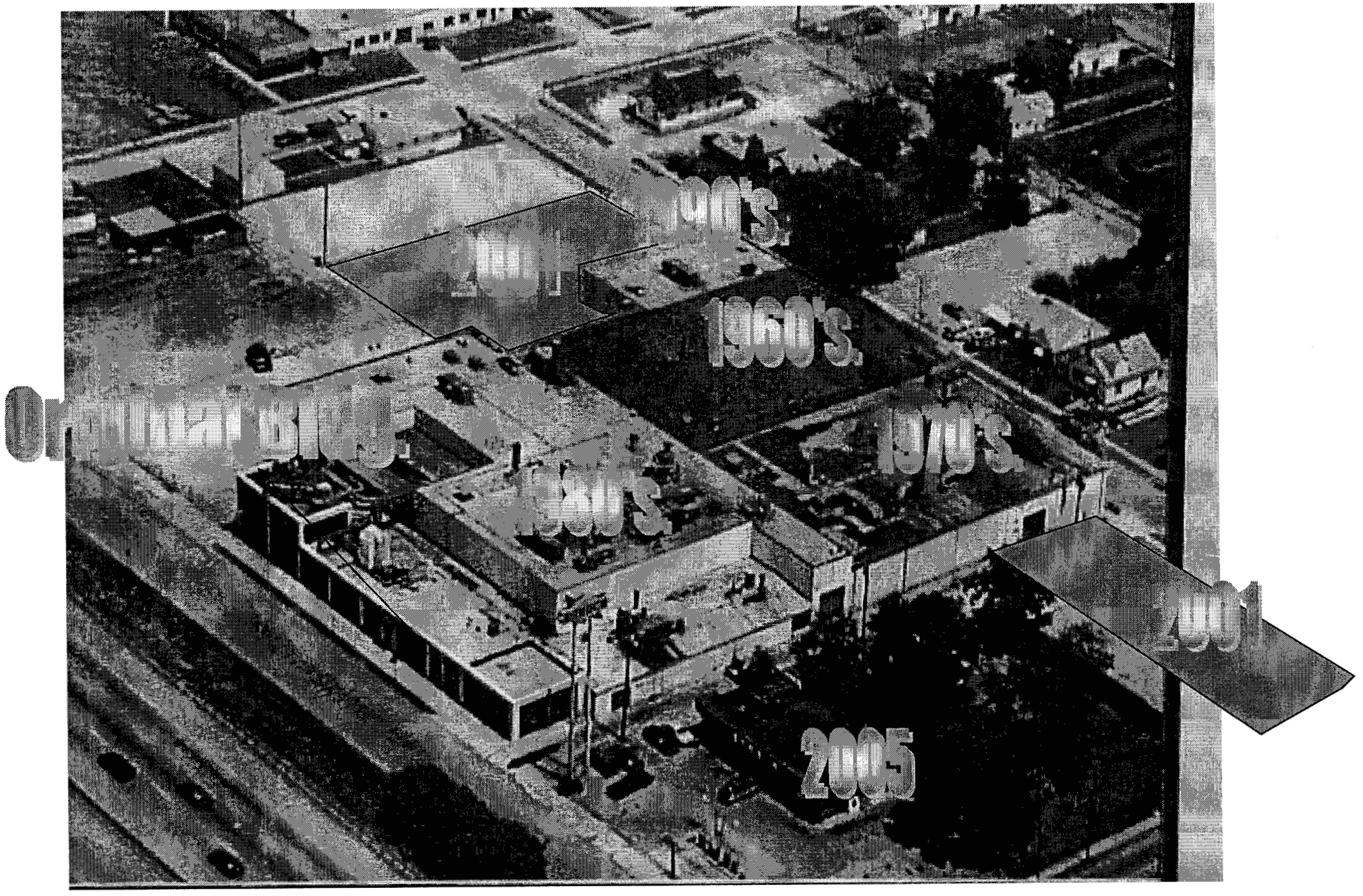
- **Industry** has grown significantly over the past 30 years and continues to grow
  - Greatest growth during race to the moon
  - Non aerospace industrial applications tied to GNP
  - Greatest growth now in PVD applications, 20% per year avg.



Growth in the field of Solid Film Lubricants (2 of 2)

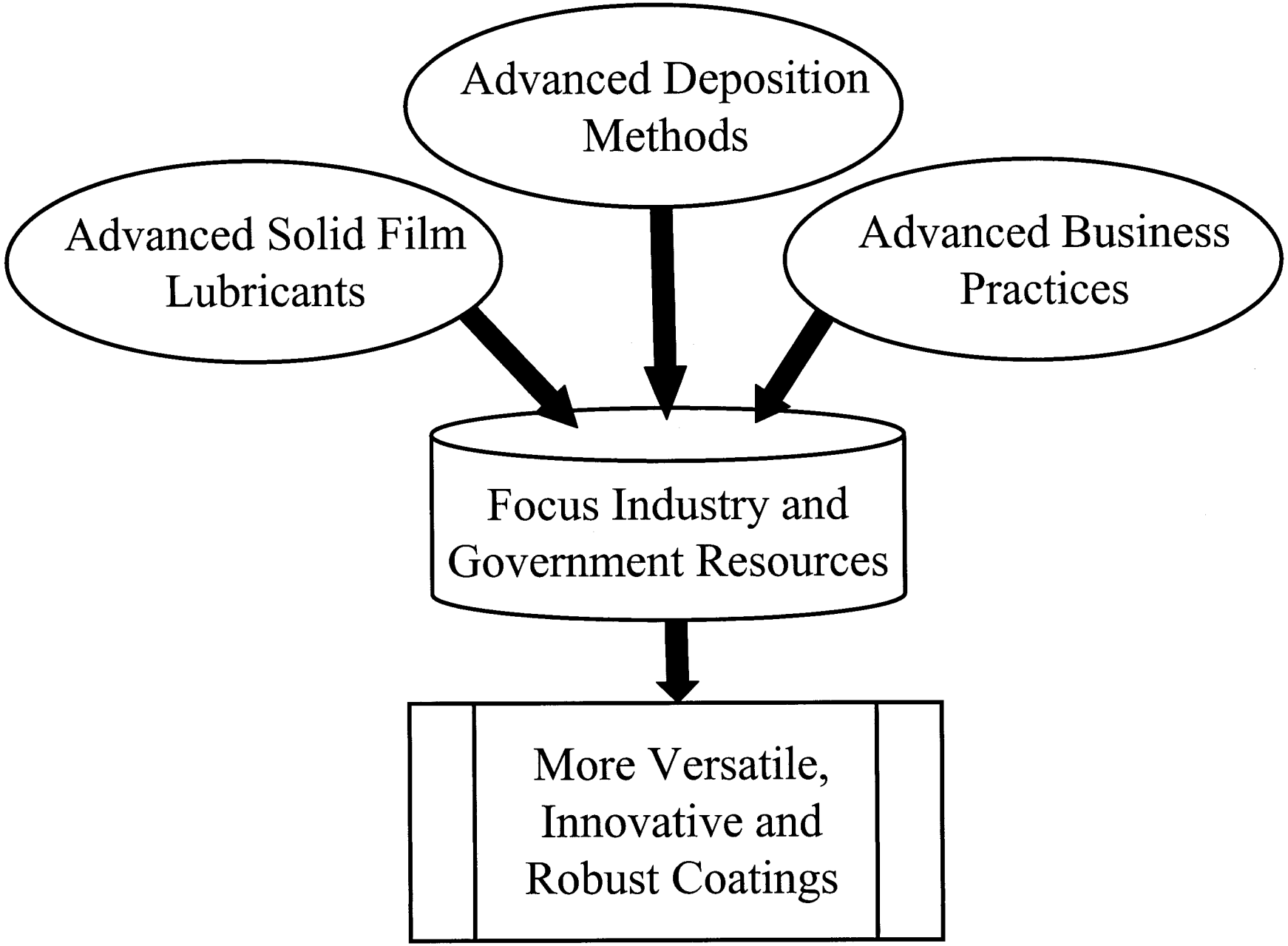
- **Extreme environments**: best applications found where conventional liquid lubes prove inadequate
- **Existing technologies** improve
- **New technologies** succeed
- **Higher performance** demands fuel technological advancements: i.e. MEMS
- Improved **consistency** and **reliability**

Plant Growth



Application Failures of Solid Film Lubricants

- Lubricant is often the limiting element in mechanical components
- Lubricated components are typically single point failures of the system
- Common causes of premature failure:
  - poor mechanism design (high contact stresses, sliding vs rolling), wrong coating selection, poor coating practices, use of coatings with poor commercialization potential, coating imperfections, uncontrolled storage conditions, poor proof testing program (prevention and detection), etc.
- Design Engineers and coating scientists need to work together


Advanced Deposition Methods
Advanced Solid Film Lubricants
Advanced Business Practices
Focus Industry and Government Resources
More Versatile, Innovative and Robust Coatings

Advanced Solid Film Lubricants

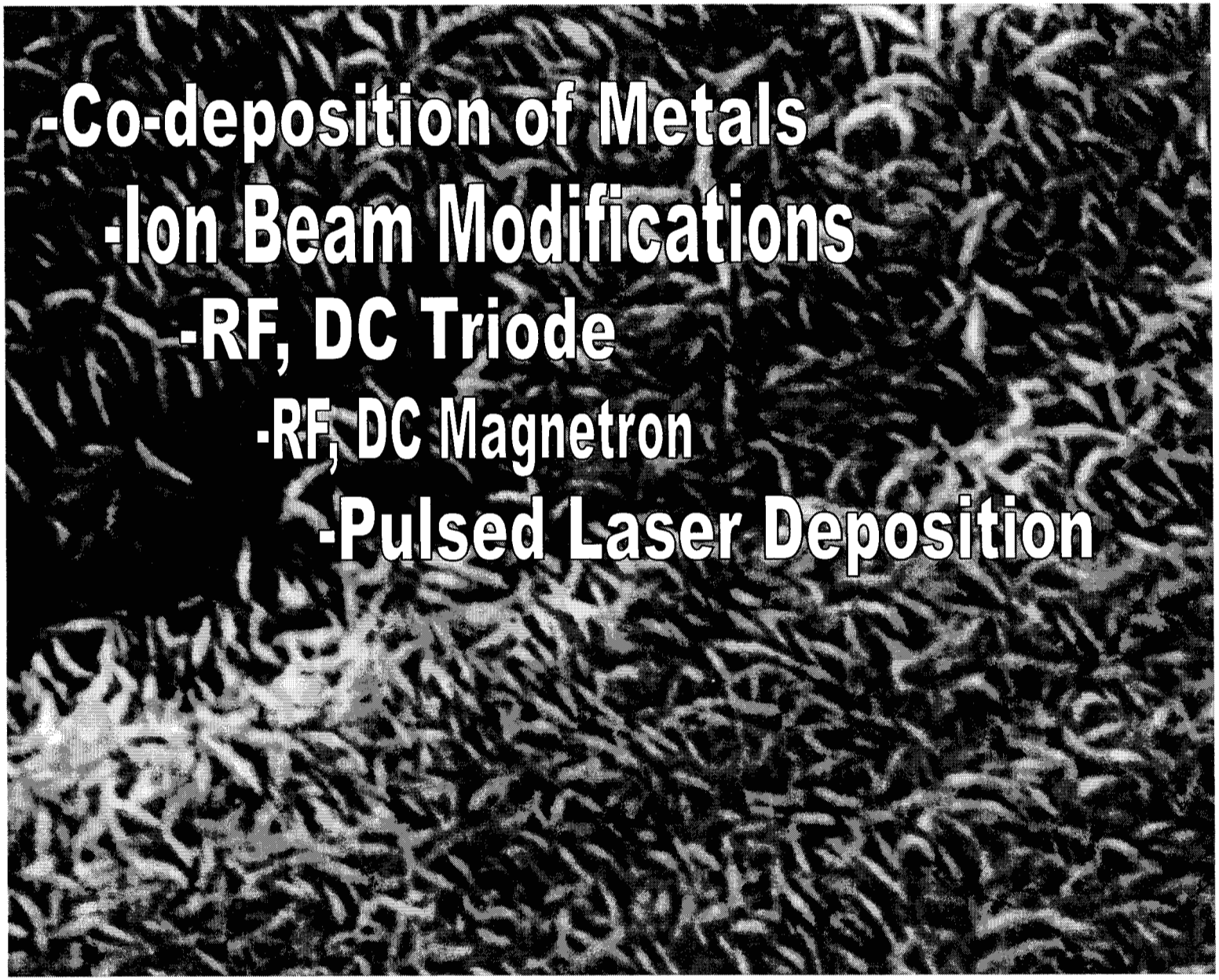
- Advances in coatings
- film chemistry, microstructure, quality, durability …

- Advances in friction and wear testing
- in-situ techniques, more applicable contact geometries, more accurate instrumentation and improved DAQ

- Advances in analytical techniques
- Surface science, resolution, sample sizes, in-situ tests, PC controls, statistical techniques

- Advances in performance
- increasing load capacity, life, environmental tolerance, reproducibility, quality, etc.

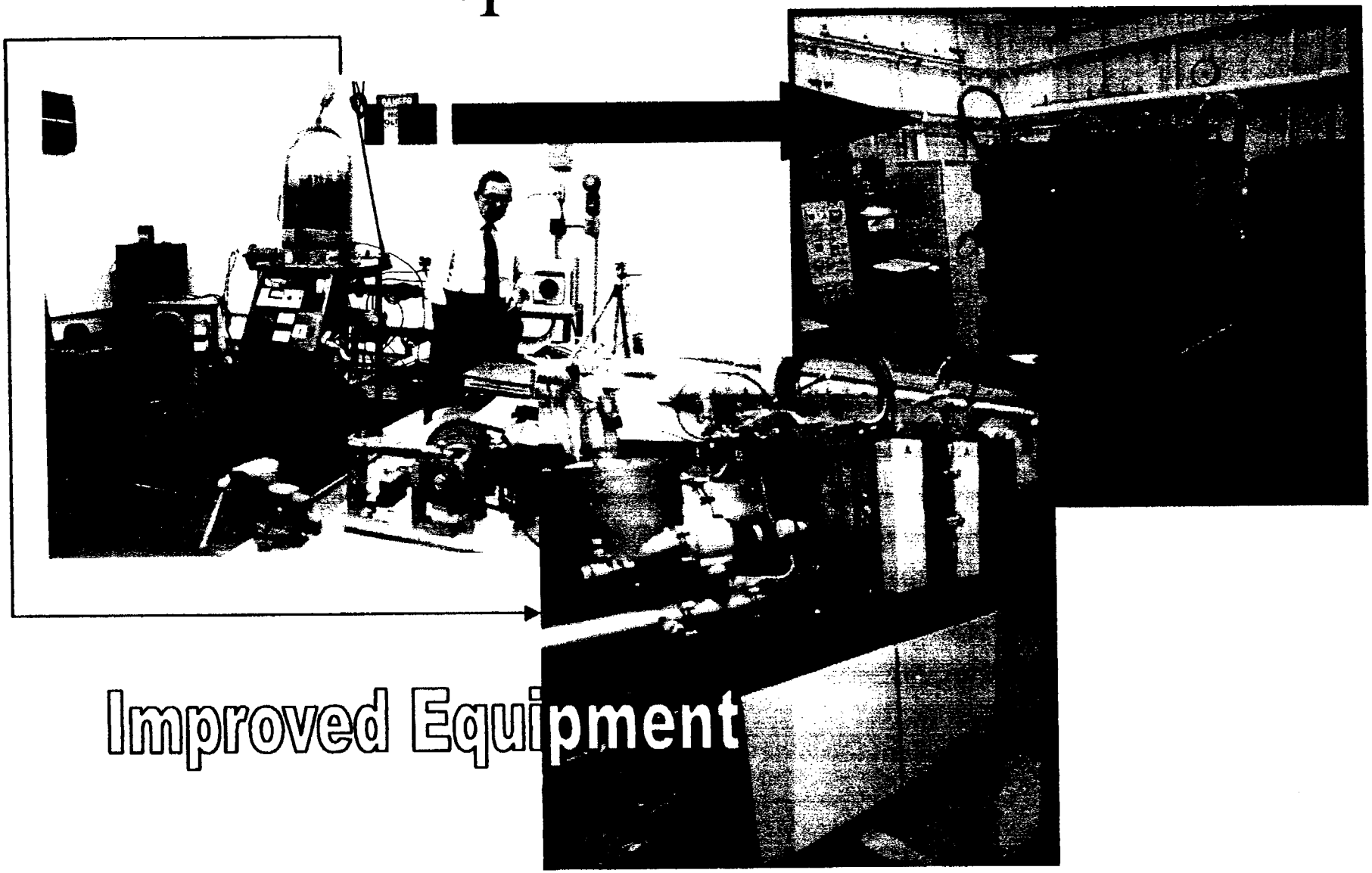
Improved Film Structure for Sputter Deposited MoS_2



Advancements in Business Practices

- Partnering customers, suppliers, government labs and universities
- Listening to the voice of the customer
- Focus on continuous improvement
- Adopting and sharing best business practices

Advancements in Solid Film Deposition Methods



Improved Equipment

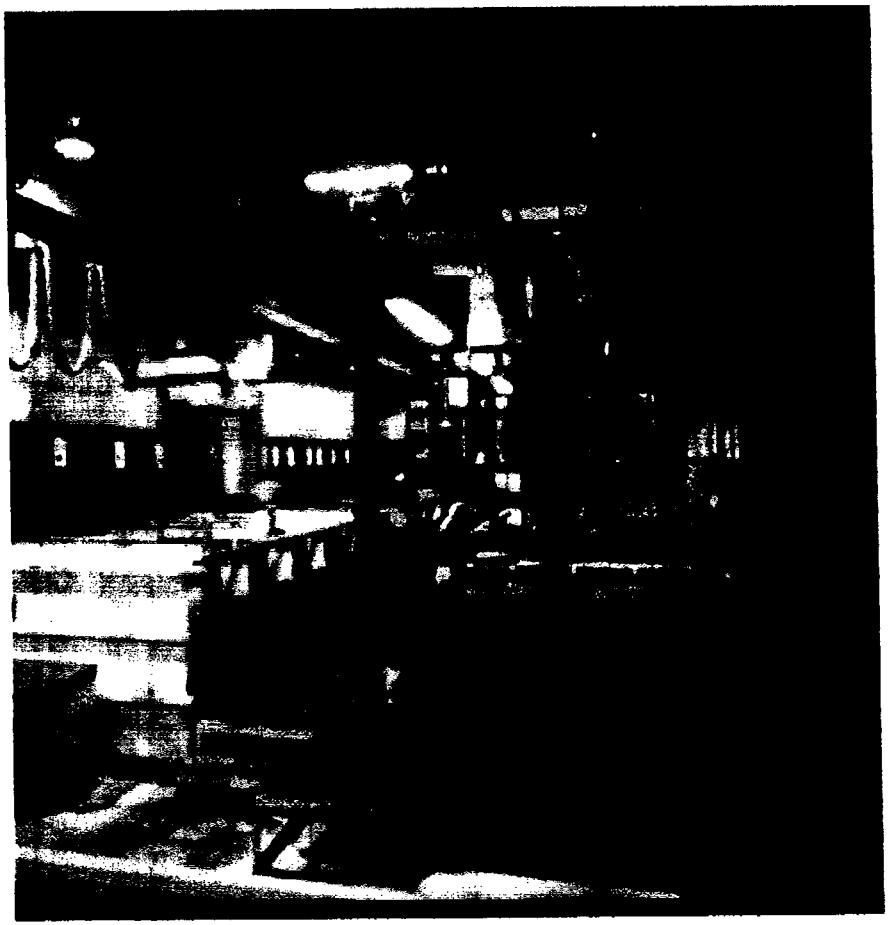
Advancements in Solid Film Deposition Methods

- Process control; computer control, computer data logging
- Process automation
- Stringent Quality Systems:

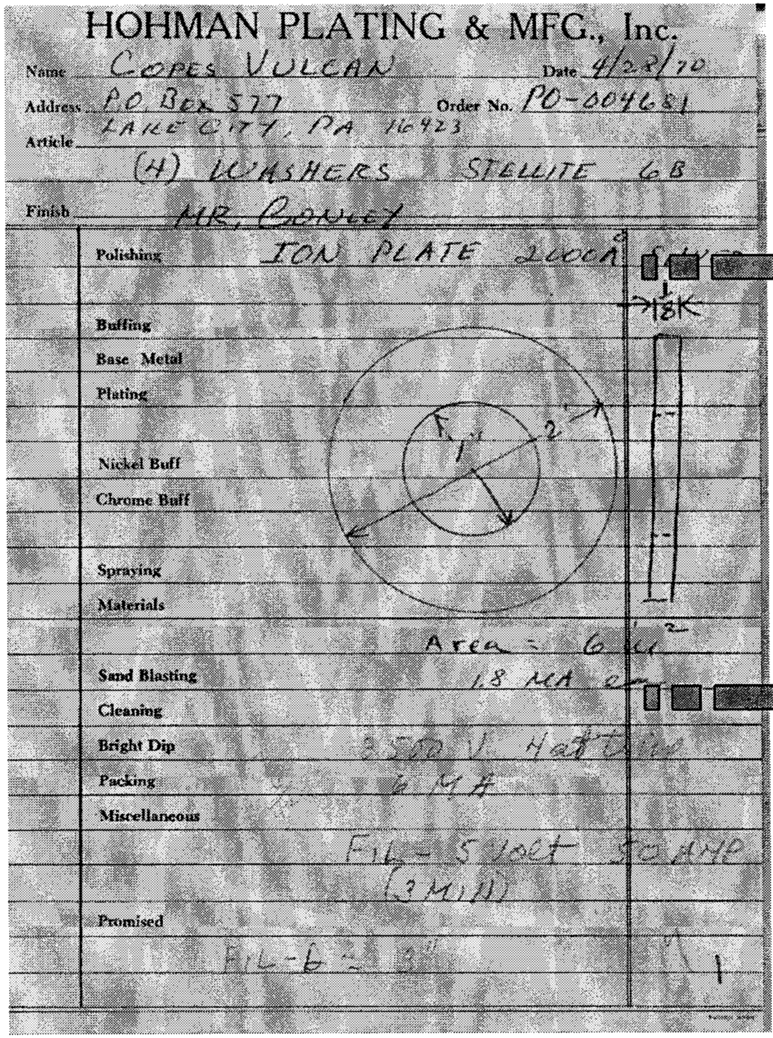
ISO, QS, AS 9000

NADCAP

Customer Specific



Process Control and Documentation



HOHMAN PLATING & MFG., Inc.

Name: Copes Vulcan Date: 4/28/70

Address: P.O. Box 577 Order No.: PO-004681

Lake City, PA 16423

Article: (4) Washers Stellite 6B

Finish: Mr. Boney

Polishing: Ion Plate 2000Å

Buffing

Base Metal

Plating

Nickel Buff

Chrome Buff

Spraying

Materials

Area = 6 in²

1.8 MA

Sand Blasting

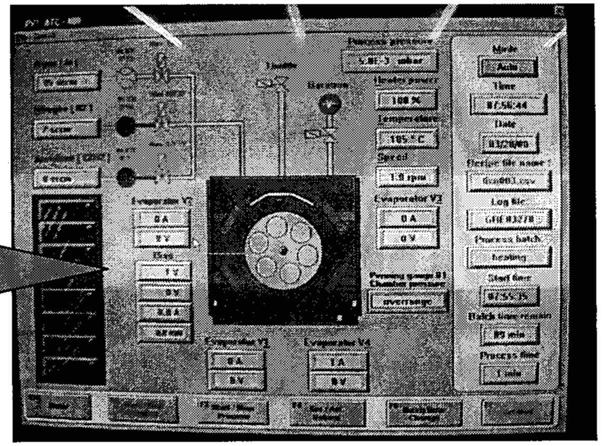
Cleaning

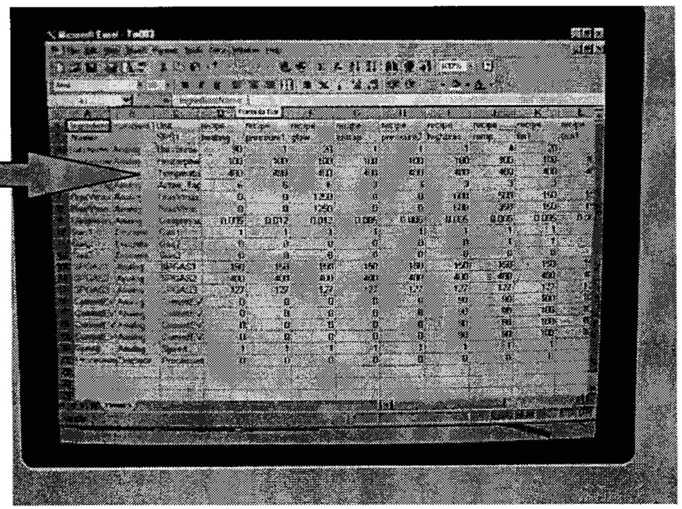
Bright Dip

Packing: 6 MA

Miscellaneous: Fil - 5 Volt 50 AMP (3 MIN)

Promised





Conventional Spray Application of Solid Film Lubricants

Long history of being applied by conventional spray methods.

Lamellar & Carbon Compounds

- Improved Chemistries: Additives, New Formulations
- Improved Equipment: Guns, fixtures, feeders, fittings
- Improved Process Control: Automation and systems, robots, indexed fixturing, XRF thickness measurements

Coating	Thickness	Part Example	Application	Tribology
MoS2/Graphite	12-25 um	Short/Long Links	Kitchen Drawer	Ease of motion
PTFE	25-50 um	Screws	Delco Assembly	Corrosion, Sticking

Thermal Spray Application of Solid Film Lubricants

Pushing the limits of high temperature (400 C +) lubrication

Lamellar, Metals, Inorganics

- Improved film chemistry: Additives, New Formulations
  - PS304, WC-CO
- Improved Equipment: Guns, fixtures, feeders, fittings, gas handling
- Improved Process Control: Automation and systems, Robots, indexed fixturing, XRF thickness measurements

Coating	Thickness	Part Example	Application	Tribology
PS-304	250-300 um	shaft	gas turbine power gen	high temp wear
Tribolube	500- 700 umdisks	Valve	Automotive	wear

Physical Vapor Deposition of Solid Film Lubes

Growth area driven by process purity and cutting tool industry

Lamellar, Carbon Compounds, Inorganics and Metals

- Improved film chemistry: dopants-nanocomposites, layering
- Improved Equipment: Ion plating, Sputtering
- Process control: Automation and systems

Coating	Thickness	Part Example	Application	Tribological Influence
MoS_2	0.5 - 1 um	bearings	satellites, rockets	friction, wear, low contamination
AlBr	25 - 40 um	shroud	gas turbine jet engines	fretting
Pb	0.2 - 0.5 um	bearings	satellite, medical x-ray	friction, wear, low contamination

Conversion Coatings Applications for Solid Film Lubricants

Growth area driven by wide applications and ease of parts processing

Carbon Compounds

- Improved film chemistry: stable baths, additives
- Improved Equipment: Parts handling, waste treatment
- Process Control: Automation and systems

Coating	Thickness	Part Example	Application	Tribology
Anodize/Teflon	45-55 um	P+G flasks	disperse powder soap	abrasion, sticking
Mn-Phosphate	5-8 um	pistons	critical dimension dry break in	galling sticking

Electro and Electroless Applications for Solid Film Lubricants

Plating continues to be widely used in industry with a heavy emphasis on environmental responsibility and worker safety

Metals and Carbon Compounds

- Improved film chemistry: stable baths, additives
- Improved Equipment: Parts handling, waste treatment
- Process Control: Automation and systems

Coating	**Thickness**	**Part Example**	**Application**	**Tribology**
Tin(Sn)	8 – 10 um	compressor piston	Auto A/C	galling
E-Ni/Teflon	5-8 /5-10um	guide rails	way wrap mach.	Styrofoam sticking

Combinational Coatings for Solid Film Lubricants

- Complex tribological problems can be solved by combining coating technologies
- Particular interest is in adaptive lubricants

Coating	Thickness	Part Example	Application	Tribology
WC-Co/E-Ni/MoS_2	~75 um/25 um/25um	brake rotor	aircraft landing	wear, corrosion, galling
Ti(C)N/MoS_2	~1 um/ 1 um	cutting tools	metal cutting	wear, friction

Conclusions

Solid Film Lubricants = Exciting Industry

- Coatings Provider
  - Solve Customer's problems
  - Commercialize laboratory coatings
  - Drive process, material, design *improvements*
  - Last in line!
- System Designer
  - Focus supplier on "tent pole" issues
  - Aid in the development of innovative coatings
  - Verify coating's effectiveness in meeting expectations
  - Feedback results to advance coatings technology